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(54) Title: METHOD FOR THE SEPARATION OF MOLTEN ALUMINIUM AND SOLID INCLUSIONS

(57) Abstract: The invention relates to a method for the separation of a dispersion of molten aluminium and solid inclusions formed from a melt of aluminium containing one or more foreign chemical elements. The invention is characterised in that molten aluminium surrounding the solid inclusions is at least essentially replaced by a molten salt.

METHOD FOR THE SEPARATION OF MOLTEN ALUMINIUM AND SOLID INCLUSIONS

The invention relates to a method for the separation of molten aluminium and solid inclusions formed from a melt of aluminium containing one or more foreign chemical elements.

During the production of aluminium one of the problems is that, depending on its subsequent use, too high a concentration of foreign chemical elements is present, both when the aluminium is produced from aluminium ore and when recycled aluminium is used. For instance aluminium scrap can contain too much Fe, Mn, Si or Mg for use for commercial purposes without mixing it with primary aluminium containing little of the foreign element. These foreign elements can be removed by cooling molten aluminium, resulting in the formation of inter-metallic compounds or crystals containing only one foreign element as solid inclusions when the molten aluminium containing the foreign elements is hypereutectic. If the molten aluminium containing the foreign elements is hypoeutectic, first foreign elements are added to make the melt hypereutectic.

When more than one foreign chemical element is present and the molten aluminium is cooled, first one inter-metallic compound or crystals containing only one foreign element is/are formed, and after that a second or even third or further inter-metallic compound or crystals will be formed.

These inter-metallic compounds or crystals are present in the molten aluminium and have to be removed to purify the molten aluminium. For the removal of the inter-metallic compounds or crystals several techniques are known, such as gravity sedimentation, flotation, filtration, centrifugation, electromagnetic sedimentation, and ultrasonic treatment. These methods offer an effective way to remove both small and large particles.

An important drawback of the known removal techniques is that quite a lot of molten aluminium is lost as interstitial aluminium for instance between the inter-metallics in the filter cake, when large quantities of inclusions are present, which results in a severe economic loss. Large quantities of inclusions are for instance present when the inclusions are formed on purpose, for instance when inter-metallics are formed in hypereutectic aluminium melts.

It is an object of the present invention to provide a method for the separation of a dispersion of molten aluminium and solid inclusions, formed from a melt of aluminium containing one or more foreign chemical elements, with which the solid inclusions can be separated from the molten aluminium such that little or no molten aluminium is lost.

It is another object of the present invention to provide a method for the separation of a dispersion of molten aluminium and solid inclusions, formed from a melt of aluminium containing one or more foreign chemical elements, which is more efficient than the known methods.

One or more of these objects are reached by the method according to the present invention, which method for the separation of a dispersion of molten aluminium and solid inclusions formed from a melt of aluminium containing one or more foreign chemical elements is characterised in that molten aluminium surrounding the solid inclusions is at least essentially replaced by a molten salt.

This means that the solid inclusions are now incorporated in the molten salt, and are no longer part of the molten aluminium, resulting in a refinement of the aluminium. It will be apparent that a thin layer of molten aluminium could still be present on the solid inclusions. The amount of molten aluminium adhering to the solid inclusions is preferably present to a maximum of 20% in weight of the solid inclusions, more preferably a maximum of 10%, and still more preferably a maximum of 5%. The use of molten salt has the advantage that the inclusions can be easily removed from the salt, and that salt is cheap as compared to aluminium, so a loss of salt is not a heavy economic loss, while on the other hand a substantial part of the salt can be reused.

Preferably, the solid inclusions are inter-metallics or crystals containing only one foreign element formed from one or more foreign elements in the molten aluminium. The method according to the invention is especially suitable for the removal of inter-metallics and foreign crystals from aluminium. However, the method according to the invention can also be used when the solid inclusions are aluminium crystals formed in the molten aluminium. When the invention is used for aluminium crystals, the purpose of the invention is not to reduce the loss of molten aluminium, but to provide a more efficient separation of the aluminium crystals from the molten aluminium containing foreign elements, such that the aluminium when re-melting the crystals is as refined as possible. At the same time, the method could be used for the removal of oxide particles, ceramic particles and/or other inclusions that are present in the molten aluminium due to the melting or cooling process or as a consequence of preceding processes.

According to a first preferred embodiment of the method according to the invention, the molten salt and the dispersion of molten aluminium with solid inclusions are subjected to a force other than the gravitation force, to transport at least part of the solid inclusions from the molten aluminium into the molten salt. It should be kept in mind that the gravitational force is usually not strong enough to replace the molten

aluminium by the molten salt. When the inter-metallics (or crystals containing only one foreign element) have a specific density that is higher than the specific density of aluminium, as is the case for most foreign elements, and a layer of the dispersion of molten aluminium and inter-metallics is present above a layer of molten salt, the inter-metallics will sink to the bottom of the layer of molten aluminium, but they will not sink into the molten salt due to the surface tension of the molten aluminium. The same holds, mutatis mutandis, when the inter-metallics and the molten salt are lighter than the molten aluminium and the inter-metallics rise in the molten aluminium.

According to the invention a force other than the gravitational force is provided, and due to this force, the solid inclusions will be able to break the surface tension of the molten aluminium and thus be transported from the molten aluminium into the molten salt. This force can be additional to the gravitation force, but that needs not be so: the force can be strong enough in itself, without help from the gravitation force, or even acting against the gravitation force.

According to a preferred way to exert the additional force, the molten salt and the dispersion of molten aluminium with solid inclusions are subjected to a mixing force in a first compartment and this mixture of molten aluminium, solid inclusions and molten salt is transported to a second compartment in which this mixture can settle in a molten aluminium phase and a molten salt phase. Here the mixing force can for instance be exerted by pouring the molten salt and the dispersion of molten aluminium and solid inclusions into the first compartment with a certain velocity. Due to the turbulence at least part of the solid inclusions will break the surface tension of the molten aluminium and be at least essentially surrounded by the molten salt. In the second compartment the mixed liquid containing the solid inclusions can settle in a molten aluminium phase and a molten salt phase, in which preferably the molten salt phase contains most or all the solid inclusions, and both phases can be tapped off separately from the second compartment. In this way the separation can be effected continuously. To achieve a better mixing force, a stirring apparatus can be present to forcibly mix the liquid in the first compartment. Preferably, one or more coalescence plates are present in the second compartment to aid in the separation of the molten aluminium phase and the molten salt phase.

Another possible way is to subject the molten salt and the dispersion of molten aluminium with solid inclusions to a mixing force and thereafter to leave the mixture to settle in a molten aluminium phase and a molten salt phase. This method can be used to provide a batch separation of the dispersion of the molten aluminium and the solid inclusions. Here too a stirring apparatus can be present during the mixing.

Another preferred way to exert an additional force is providing a layer of molten salt in contact with a layer of the dispersion of molten aluminium with solid inclusions, wherein the layer of molten salt and/or the layer of the dispersion of molten aluminium with solid inclusions is subjected to a stirring force. Due to the stirring of one or both of the layers, the contact surface between the molten aluminium layer and the molten salt layer will be ruptured and droplets of the molten aluminium with the inclusions will get into the molten salt, and droplets of the molten salt will get into the molten aluminium with inclusions. Due to the continued stirring some of the droplets of aluminium will be reduced until only the inclusion(s) that were present in the droplet are left, which are thus part of the layer of molten salt.

For the above preferred ways to exert the additional force, preferably the salt used has a specific density that is higher than the specific density of the aluminium. This is because most inter-metallics also have a specific density that is higher than the specific density of aluminium. When both the salt and the solid inclusions have a specific density that is higher than the density of aluminium, the gravitational force will add to the replacement of molten aluminium by molten salt during the separation according to the invention as described above. For some foreign elements, however, the inter-metallics have a specific density that is lower than the density of aluminium, and in such a case the salt used should have a specific density that is lower than the density of aluminium.

According to another preferred way to exert an additional force, the molten salt and the dispersion of molten aluminium with solid inclusions are subjected to a centrifugal force. Due to the centrifugal force the solid inclusions such as the inter-metallics which have a higher specific density than the molten aluminium, are subjected to a higher force than the molten aluminium because the centrifugal force is directly proportional to mass. The force on the solid inclusions will now be high enough to break the surface tension of the molten aluminium if the centrifugal force is high enough. The solid inclusions having a higher specific density than the molten aluminium will thus be transported from the molten aluminium into molten salt having a higher specific density than the molten aluminium. The same holds when the solid inclusions and the molten salt have a lower specific density than the molten aluminium.

According to still another preferred way the molten salt and the dispersion of molten aluminium with solid inclusions are subjected to an electromagnetic force. The electromagnetic force only acts on materials which have an electric conductivity. Since aluminium has a very high electric conductivity, whereas molten salt has a low electric conductivity and inter-metallics have an electric conductivity that is virtually zero, when

the molten salt and the dispersion of molten aluminium with solid inclusions such as inter-metallics are subjected to an electromagnetic force, the molten aluminium is forced in one direction and the molten salt is forced in the other direction, whereas at the same time the solid inclusions will be subjected to a strong force from the molten aluminium into the molten salt. The dispersion of molten aluminium with solid inclusions is thus separated. When the electromagnetic force is used to separate the solid inclusions from the molten aluminium, the density of the solid inclusions and the salt is not important as such.

According to yet another preferred way to exert an additional force, the interface between the molten salt and the molten aluminium is perturbed, for instance by bubbling with a gas, or by flotation when the molten salt has a specific density that is lower than the specific density of molten aluminium. The perturbing of the interface results in the local disruption of the interface between the molten aluminium and the molten salt and thus in the reduction of the surface tension between the molten salt and molten aluminium. In this way the solid inclusions can be transported from the molten aluminium into the molten salt. The interface can for instance be perturbed by bubbling with gas, which is a known technique in steel making, or by flotation, which also is a known technique.

According to a second preferred embodiment of the method according to the invention, the solid inclusions are first concentrated, such as by filtering from or by settling in the dispersion of molten aluminium with solid inclusions to form a cake containing solid inclusions and molten aluminium, and after the concentration the molten salt is used to wash molten aluminium out of the cake. The known filtration techniques have the disadvantage that in between the filtered solid inclusions quite a lot of molten aluminium is still present. Without any further separation methods, this aluminium would be lost. Using the method according to the invention, a large part of the molten aluminium in the cake is replaced by molten salt, and the molten aluminium from the cake is removed with the molten salt used for the washing and can be easily separated thereof, for instance by settling.

When the above embodiment of the method according to the invention is used for the separation of the molten aluminium and the solid inclusions, it is possible that the concentration and the washing are performed alternately. In this way a new cake is formed and washed each time, and the concentrated inclusions are removed each time. This alternation can be used as a batch process, but also as a continuous alternation.

It is also possible that the concentration and washing are performed as a continuous process. For this method, a rotating filter such as a rotary drum filter can be used, from which the filtered and washed inclusions can be removed for instance by scraping it off the filter.

According to one preferred method, when washing the filter cake an underpressure is used to draw the molten salt through the filter cake. The underpressure provides enough driving force for essentially replacing the molten aluminium in the filter cake by the molten salt.

According to another preferred method, the molten salt is pressed through the filter cake using an overpressure. In this way the overpressure provides the driving force for essentially replacing the molten aluminium in the filter cake by the molten salt.

It is moreover possible that a wash column is used to filter the solid inclusions from the dispersion of molten aluminium and solid inclusions to form the filter cake, wherein the molten salt is used to wash molten aluminium countercurrently out of the filter cake. It is known to use a wash column to refine aluminium, as described in European patent application EP 0.954.616, where the wash column is used for the fractional crystallisation of aluminium and the purified crystals are washed using molten purified aluminium.

CLAIMS

1. Method for the separation of a dispersion of molten aluminium with solid inclusions formed from a melt of aluminium containing one or more foreign chemical elements, characterised in that molten aluminium surrounding the solid inclusions is at least essentially replaced by a molten salt.

2. Method according to claim1, wherein the solid inclusions are inter-metallics or crystals containing only one foreign element formed from one or more foreign elements in the molten aluminium.

3. Method according to claim1, wherein the solid inclusions are aluminium crystals formed in the molten aluminium.

4. Method according to any one of the claims 1 - 3, wherein the molten salt and the dispersion of molten aluminium with solid inclusions are subjected to a force other than the gravitational force, to transport at least part of the solid inclusions from the molten aluminium into the molten salt.

5. Method according to claim 4, wherein the molten salt and the dispersion of molten aluminium with solid inclusions are subjected to a mixing force in a first compartment and this mixture of molten aluminium, solid inclusions and molten salt is transported to a second compartment in which this mixture can settle in a molten aluminium phase and a molten salt phase.

6. Method according to claim 5, wherein one or more coalescence plates are present in the second compartment to aid in the separation of the molten aluminium phase and the molten salt phase.

7. Method according to claim 4, wherein the molten salt and the dispersion of molten aluminium with solid inclusions are subjected to a mixing force and thereafter the mixture is left to settle in a molten aluminium phase and a molten salt phase.

8. Method according to claim 4, wherein a layer of molten salt is in contact with a layer of the dispersion of molten aluminium with solid inclusions, and wherein

the layer of molten salt and/or the layer of the dispersion of molten aluminium with solid inclusions is subjected to a stirring force.

9. Method according to any one of claims 4 - 8, wherein the salt used has a specific density that is higher than the specific density of the aluminium.

10. Method according to claim 4, wherein the molten salt and the dispersion of molten aluminium with solid inclusions are subjected to a centrifugal force.

11. Method according to claim 4, wherein the molten salt and the dispersion of molten aluminium with solid inclusions are subjected to an electromagnetic force.

12. Method according to claim 4, wherein the interface between the molten salt and the molten aluminium is perturbed, for instance by bubbling with a gas, or by flotation when the molten salt has a specific density that is lower than the specific density of molten aluminium.

13. Method according to any one of claims 1 - 3, wherein the solid inclusions are first concentrated, such as by filtering from or by settling in the dispersion of molten aluminium with solid inclusions, to form a cake containing solid inclusions and molten aluminium, and wherein after the concentration the molten salt is used to wash molten aluminium out of the cake.

14. Method according to claim 13, wherein the concentration and the washing are performed alternately.

15. Method according to claim 13, wherein the concentration and washing are performed as a continuous process.

16. Method according to claim 13, 14 or 15, wherein an underpressure is used to draw the molten salt through the cake.

17. Method according to claim 13, 14 or 15, wherein the molten salt is pressed through the cake using an overpressure.

18. Method according to claim 13, wherein a wash column is used to filter the solid inclusions from the dispersion of molten aluminium and solid inclusions to form the filter cake, and wherein the molten salt is used to wash molten aluminium countercurrently out of the filter cake.